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RESEARCH MEMORANDUM

EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF ROOT RESTRAINT ON THE FLUTTER OF A SWEPTBACK,
UNIFORM, CANTILEVER WING WITH A VARIABLY
LOCATED CONCENTRATED MASS

By John E. Tomassoni and Herbert C. Nelson

Langley Aeronautical Laboratory LOAN FROM THE FILES OF Langley Air Force Base, Va.

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SUMMARY

Data from 129 flutter tests conducted in the Langley 4.5—foot flutter research tunnel have been compiled and are reported. The investigation was carried out to obtain information which would test the validity of the assumption of root restraint used commonly in the flutter analyses of swept wings. This investigation was made with wings of 45° and 60° angles of sweepback each having two different lengths. Each configuration included a concentrated mass located at various spanwise positions and at two chordwise positions.

The data obtained provided results which indicate that the assumption of root restraint is fairly well justified, at least for swept wings having length—to—chord ratios of the order of 4.5. However, none of the wings tested with the roots perpendicular to the leading edge showed exactly the same flutter trends over a range of spanwise weight positions as those obtained with the corresponding wing having the root parallel to the stream direction.

INTRODUCTION

The boundary conditions at the root of a sweptback wing make the problem of an exact structural analysis very complicated. In order to circumvent this difficulty, the following simplifying assumptions are sometimes made: that (1) the root is rigidly restrained normal to the elastic axis, and (2) the elastic axis is a straight line. With these assumptions and with the air forces, modified for sweep by the method of reference 1. a flutter analysis of a sweptback wing can be made.

The purpose of this paper is to present experimental data on the flutter characteristics of weighted sweptback wings clamped at the root to approximate the conditions of the previously mentioned assumptions. The models used in the investigation are similar to the swept models of reference 2 but are modified by root—stiffening plates and change of length. The lengths of the models were measured along the elastic axis which was located at the midchord.

By approximating the simplifying assumptions of theory in regard to root restraint and elastic axis, the data presented provide a means of evaluating the sufficiency of theory regarding structural representation and air-force evaluation.

SYMBOLS

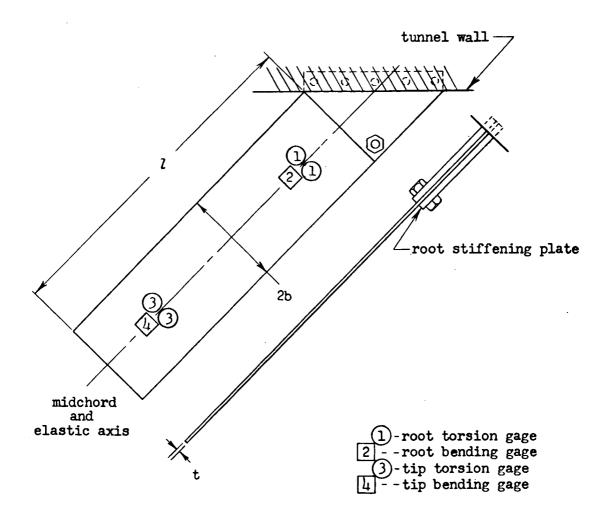
w	weight of wing section, pounds per inch
$W_{\mathbf{w}}$	weight of concentrated weight, pounds
ı	length of midchord line, feet
Ъ	half chord of wing section measured perpendicular to the midchord line, feet
t	thickness of wing section, inches
Λ	sweep angle measured from an axis perpendicular to air stream in plane of wing to elastic axis, degrees, positive for sweepback
x_{α}	distance from elastic axis to center of gravity of wing section, referred to half chord, positive rearward
e _w	distance from elastic axis of wing section to center of gravity of weight, referred to half chord, negative for forward weight location
\mathbf{I}_{CG}	mass moment of inertia of wing section about its center of gravity, inch-pound-second ² per inch
I _{EA}	mass moment of inertia of wing section about its elastic axis, inch-pound-second 2 per inch

I _w	mass moment of inertia of weight about its center of gravity, inch-pound-second ²
EI	bending rigidity of wing section, pound-inch2
GJ	torsional rigidity of wing section, pound-inch2
m	mass of wing per unit length, slugs per foot
ra	nondimensional radius of gyration of wing section about its elastic axis $\left(\sqrt{\frac{T_{EA}}{mb^2}}\right)$
$q_{\mathbf{f}}$	dynamic pressure at flutter, pounds per square foot
ρ	air density at flutter, pounds per square foot
$v_{\mathbf{f}}$	stream velocity at flutter, feet per second
κ	wing mass-density ratio at flutter $\left(\frac{\pi \rho b^2}{m}\right)$
g _h , g _a	structural damping coefficient in bending and torsional degree of freedom, respectively

APPARATUS

The experimental results presented herein have been obtained in the Langley 4.5—foot flutter research tunnel with air used as the testing medium under atmospheric conditions. In this investigation models B-1 and B-2 were the same as model B of reference 2 except as modified by the root stiffening plates and change of length. Models C-1 and C-2 were of as nearly the same dimensions as model C of reference 2 as manufactured 0.090—inch aluminum sheet stock would permit and were

also modified by root stiffening plates and change of length. The accompanying sketch shows how the $\frac{1}{2}$ -inch-thick root stiffening plates were attached to the models.



Small changes in the wing length were included to determine if a single effective length could be found which would give the same flutter speeds as the corresponding model of reference 2. The following table lists the models with their respective lengths and sweep angles:

Model	l (ft)	Λ (deg)
B (reference 2) B-1 B-2	3.00 2.75 2.83	} 45
C (reference 2) C-1 C-2	3.00 2.75 3.00	60

The section properties of the wings are as follows:

Chord, 2b, feet
Airfoil section Flat plate
g _h , nondimensional 0.01 (approx.)
g_{α} , nondimensional 0.005 (approx.)
t, inches
w, pounds per inch
I_{CG} , inch-pound-second ² per inch
I_{EA} , inch-pound-second ² per inch
EI, pound—inch ² 0.00506 x 10^6
GJ, pound—inch ² 0.008 \times 10 ⁶
x_{α} , nondimensional 0.0
r_{α}^2 , nondimensional
$1/\kappa$, (standard air density, no concentrated weight) 34.1

Two weights which were essentially the same were used in the tests. One was attached at various positions along the leading edge and the other along the midchord line of each model. The weight properties are:

Item	Leading-edge weight	Midchord weight
W _w , lb	3.12	3.12
. Θ _₩	-1.0	0
I _w , inlb-sec ²	0.010	0.0098

Strain gages cemented on the wings used in conjunction with a recording oscillograph provided a means for obtaining the frequencies and phase relationships of the torsional and bending strains at the gage locations. The positions at which the strain gages were attached to the models are shown in the preceding sketch. The gage traces on each of the oscillograph records in figure 1 are numbered from left to right and represent the response of the root-torsion, root-bending, tip-torsion, and tip-bending gages, respectively. The fifth trace on the records is an imposed calibration frequency. The apparatus section of reference 2 gives a complete description of the method used to obtain the phase angles listed in table I.

The attenuation marked on each gage trace is a scale number obtained by electrical multiplication where the value of the attenuation is inversely proportional to the magnification of response. The amplitudes of the traces combine with the attenuation to give relative stresses, torques, or moments. These relative values are obtained in the following manner, the first two traces of a record being used as an example:

$$\frac{\text{Stress (1)}}{\text{Stress (2)}} = \left(\frac{\text{Attenuation (1)}}{\text{Attenuation (2)}}\right) \left(\frac{\text{Amplitude (1)}}{\text{Amplitude (2)}}\right)$$

TEST PROCEDURE

An investigation at zero airspeed was conducted before each series of tests to obtain the first three natural frequencies for each span—wise weight position. Several spanwise positions of the concentrated weight for a constant chordwise station constituted a series for one model. During each test the airspeed in the tunnel was increased slowly. At the critical flutter speed the tunnel conditions were observed, and an oscillograph record of the model vibrations was taken. The tunnel airspeed was then reduced immediately after the critical flutter speed was attained in order to prevent the model from being destroyed. The models were tested initially without any weight and each of the series of tests was accomplished by moving the weight progressively spanwise to the tip. After a series of tests was completed the model was retested without the weight to provide knowledge of any possible damage which may have occurred. No difference was found to exist.

PRESENTATION AND DISCUSSION OF RESULTS

This paper presents the experimental data obtained from flutter testing 45° and 60° sweptback wings with the roots modified by stiffening plates. In all plots the test results are presented as functions of the wing length 1.

The experimental results are compiled in table I. The dynamic pressure, flutter speed, Mach number, and the first three natural frequencies for each weight position and the corresponding flutter frequencies are listed. Also the phase relationships of the torsional and bending stresses at the gage locations for the second and third natural and flutter frequencies are given. The Reynolds number for each series of tests is given and the chord length used in its determination was the length parallel to the air stream. A sketch of each model tested is included in table I with its corresponding data.

The oscillograph records taken at flutter for the various cases tested are shown in figure 1. The four traces on the records in the top row only, which represent the vibratory motions of the model, are numbered, but these numbers pertain in the same order to all records. Each is marked with its appropriate attenuation. The unusual type of flutter involving two frequencies simultaneously, as reported in reference 2, also occurred in a few cases during the present tests.

The flutter data of figure 2 show the validity of the commonly used assumptions regarding root restraint for the models tested. In general, the differences between the data from a given unmodified wing and that from the corresponding wing having a modified root are small, indicating that the assumptions are fairly well justified.

The differences in the flutter speed when the concentrated weight was on the wing leading edge were small. This indicates that as the length of the wing with the modified root was increased (B-1 to B-2 or C-1 to C-2) the flutter speed approached that of the unmodified wing (B or C, respectively) for the range of spanwise weight locations 0 to 45 percent 1. From the 65 to about 100 percent spanwise weight range an opposite trend is noted. In the range from 45 to 65 percent 1 an irregular variation exists.

The data for the weight at the midchord line indicate that as the length of the wing was increased the flutter speed approached that of the unmodified wing over both the 0 to 45 percent and the 65 to 100 percent spanwise weight ranges while the range from 45 to 65 percent was irregular.

In figure 3 the first three natural and the flutter frequencies are plotted against spanwise weight position for each of the series of tests. These plots show the relation between the flutter frequency and the first three natural frequencies for each of the configurations tested.

CONCLUDING REMARKS

The structural assumptions usually made in the flutter analysis of swept wings, that the root is rigidly restrained and the elastic axis is a straight line at least for the uniform type of wing tested, appear to be fairly well justified. Exceptions are noted for critical ranges of concentrated weight positions where small changes in the position of the weight produce relatively large changes in the experimentally determined flutter speed.

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REFERENCES

- 1. Barmby, J. G., Cunningham, H. J., and Garrick, I. E.: Investigation of the Effects of Sweep on the Flutter of Cantilever Wings. NACA RM L8H30, 1948.
- 2. Nelson, Herbert C., and Tomassoni, John E.: Experimental Investigation of the Effects of Sweepback on the Flutter of a Uniform Cantilever Wing with a Variably Located Concentrated Mass.
 NACA RM L9F24, 1949.

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		9	4	Mach	Distance of weight		Frequ	Frequencies (cps)			(Re	Ph: bendi	ng a	ngle r nd tor nence (d	relati orsione e strai	fons!	Phase-angle relationship of bending and torsional stresses (Ref. = Reference strain-gage trace) (deg)	(60)		
Model	룊	(lb/sq ft)		number			Natural		: !		nature	2nd natural mode		3rd natural mode	ural	mode		Flutter mode	mode	_
						lst	2nd	374	Flutter	ı,	CU .	en en		1 2	<u></u>	#		a	3	.⇒'
Model B-1	1	34.51	175.8	0.1535	0	2.61	2.61 16.19	20.97	13.70		Ref.	•	180 Ref.	J	· ;		Ref.	84	8	87
Swept, uncapered wing; A = +7 Weight moved along leading edge; e, = -1	Ω	35.85	179.3	179.3 0.1565	3.03	2.61	2.61 16.09	21.13	13.63		Ref.	- 1	180 Ref.		0	:	Ref.	95	59	0
Reynolds number ≅ 5208.9v _f	m	34.70	176.6	176.6 0.1540	60.6	2.63	15.48	19.81	12.78	Ref.		•	B	Ref.	0	180	Ref.	45	27	22
	#	30.69	165.9	0.1445	15.15	2.63	म. टा	18.57	11.21	Ref.	0	ı	O	Ref.	0 0	180	Ref.	†72	0	8
	Ţ	25.81	152.1	0.1324	21.21	2.56	9.86	18.18	₩2.6	Ref.	0		O Re	Ref.	0		180 Ref.	0	0	33
*	9	28.40	159.7	0.1390	27.27	2.56	8.62 18.00	18.00	8.06	Ref.	.0	•	O Re	Ref.	0 0		180 Ref.	0	7,12	33
THE	7	45.71	203.2	203.2 0.1770	33.33	2,47	7.78 18.18	18.18	7.14	Ref.	0		O Re	Ref.	0 0		180 Ref.	88	77	267
34 O - 1	∞	84.78	283.1	0.2470	39.39	2.25	7.52	17.86	15.91	Ref.	0	•	O Re	Ref.	0 0		180 Ref.	0	0	256
	6	93.79	293.4	293.4 0.2560	45.45	2.17	7.52	17.65	15.59	Ref.	0	,	O Re	Ref.	0	180	Ref.	27	38	0
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	ដ	119.60	333.1	333.1 0.2905	51.51	2.04	7.84	17.31	17.16	Ref.	-	•	0	Ref.	0	180	Ref.	0	21	99
	ョ	245.50	494.5	0.4285	57.57	1.81	8.33	8.33 16.90	01•€†	Ref.	1	•	O	Ref.	0	180	Ref.	60	180 3	302
>	검	236.10	8.484	0.4190	63.63	1.72	6.00	16.63	31.90	Ref.	0	. •	O Ref.		0	180	Ref.	0	0 1	180
	13	178.40	416.9	416.9 0.3600	69.69	19.1	10.01	16.35	16.67	Ref.	0	0	O Ref.		0		180 Ref.	0	277	288
» •	큐	74.27	263.9	0.2270	75.75	1.51	10.63	16.09	16.39	Ref.	0	۰,0	O Ref.		0 0		180 Ref.	177	353 2	182
•	15	35.15	180.7	180.7 0.1550	81.81	1.41	10.11	15.95	16.10	Ref.	0	0	O Ref.	£. 180	9	0	Ref. 170	170	ਲ	0
	16	19.70	134,8	0.1155	87.87	1.26	10.94	15.60	41.20 13.68	Ref.	0	. i	Re	Ref. 180	9	٥	Ref.	٥	243	336
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Model B-1 Swept, untapered ving; $\Lambda = 45^{\circ}$ Weight moved along midchord line; $\mathbf{a_{v}} = 0$ Pearon de mumbre 2 felix fre		8	Ą	Масъ	Distance of weight		Frequencies (cps)	encies ps)	_		(Re	bending and torstonel stresses (Ref. = Reference strain-gage trace) (deg)	ng and Refere	tore mce e (de	itona. train g)	ading and torsional stress = Reference strain_gage tra (deg)	eesses o tra	(60)	
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d line; ew =	· 67	34.07	178.6	0.1525	0	2.61	16.19	20.97	13.29		Ref.	- 15	180 Ref.		0		Ref.	8	82
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	81	34.06	178.2	0.1525	21.21	19.5	12.42	21.59	11.48		Ref.		O Ref.	:	0		Ref.	32	0
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0 53 33.11 166.2 0.1499 5.88 2.44 15.00 20.3 12.20 Ref. Ref 0 Ref. 139 0 6 6 33.39 166.2 0.1499 5.88 2.44 15.09 20.50 12.60 Ref. Ref 0 Ref. 150 0 6 6 6 33.39 176.7 0.150 25.39 2.44 10.71 20.00 10.59 Ref 0 Ref 0 Ref. 170 0 6 6 178.7 0.1610 29.40 2.31 9.46 19.30 9.61 Ref 0 Ref 0 Ref. 170 0 6 6 178.7 0.1610 29.40 2.31 9.46 19.30 9.61 Ref 0 Ref 0 Ref. 170 0 6 6 178.7 0.1610 29.40 2.31 9.48 19.30 9.61 Ref 0 Ref 0 Ref. 170 0 6 6 178.7 0.1610 29.40 2.31 9.48 19.30 9.61 Ref 0 Ref 0 Ref. 170 0 6 178.7 0.1610 29.40 2.31 18.84 18.45 13.50 Ref 0 Ref 0 Ref. 120 0 6 18.31 179.4 0.1613 47.06 2.02 9.28 8.93 18.68 13.50 Ref 0 Ref 0 Ref. 129 0 6 19 35.11 170.4 0.1613 47.06 2.02 9.28 177.2 13.50 Ref 0 Ref 0 Ref. 129 0 6 19 35.11 170.4 0.1613 47.0 1.20 13.50 Ref 0 Ref 0 Ref. 129 0 6 19 35.11 170.8 120 120 120 120 120 120 120 120 120 120							lat	Bi		Flutter	<u> L</u>	2	3	#	1	8	<u> </u>				-
9 33.11 166.2 0.1499 5.08 2.44 15.25 20.60 12.60 Ref. Ref 0 Ref. 180 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Model B-2	22	32.18	163.9	0.1479	0	± .c	15.00 %	20.3	12.20				Ref.		1			r. 19	80	916
54 33.98 168.7 0.1920 11.76 2.45 14.10 20.50 12.60 Bar 0 Rar 0 Rar. 120 0 0 1 33.98 168.7 0.1920 25.53 2.44 10.71 20.00 10.59 Bar 0 Rar 0 Rar. 170 0 1 2 39.33 179.4 0.1650 35.29 2.28 8.93 18.68 13.90 Bar 0 Bar 0 Rar. 170 0 1 2 39.33 179.4 0.1655 41.18 2.14 8.84 18.45 13.50 Bar 0 Bar 0 Bar. 170 0 1 2 39.33 179.4 0.1655 41.18 2.14 8.84 18.45 13.50 Bar 0 Bar 0 Bar. 170 0 1 2 39.33 179.4 0.1655 41.28 2.24 13.80 15.80 13.50 Bar 0 Bar 0 Bar. 120 0 1 2 39.31 179.4 0.1655 41.28 13.50 13.50 Bar 0 Bar 0 Bar. 120 0 1 2 39.31 179.4 0.1655 11.28 13.50 15.80 15.	Swept, untapered wing; A = 45 Weight moved along midchord line; Q _w = 0 Rewnolds number = 6060.89.	53	33.11	166.2	0,1499		ा पाप ट	15.25	20.60	12.60	-			Ref.				- #		g.	91 0
55 38.13 176.7 0.15c0 29.40 2.31 9.48 19.30 9.61 Ref 0 Ref 0 Ref. 170 0 56 38.13 176.7 0.1609 35.29 2.28 8.93 18.63 13.50 Ref 0 Ref 0 Ref. 170 0 58 38.33 179.4 0.1613 41.18 2.14 8.84 18.45 13.50 Ref 0 Ref 0 Ref. 170 0 59 35.11 171.8 0.1545 47.06 2.02 9.35 17.72 13.50 Ref 0 Ref 0 Ref. 199 0 60 33.09 166.8 0.1499 52.94 1.68 16.81 13.40 Ref 0 Ref 0 Ref. 199 0 62 54.12 214.3 0.1925 64.77 1.61 12.35 16.45 18.67 Ref 180 Ref 0 Ref. 159 0 63 50.16 206.2 0.1491 76.47 1.51 12.35 16.45 18.67 Ref 0 Ref 0 Ref. 159 0 64 48.65 203.1 0.1823 76.47 1.41 13.51 13.80 16.13 Ref 0 180 Ref 0 Ref. 159 0 65 45.22 175.1 0.1570 94.12 1.14 12.10 13.16 14.3 Ref 0 180 Ref 0 Ref. 159 0 65 36.22 175.1 0.1570 94.12 1.14 12.10 13.16 14.3 Ref 0 180 Ref 0 Ref. 159 0		九	33.98	168.7	0.1520		2.45	14.10	20.50	97 टा					_				r. 18	g.	
56 38.13 178.7 0.1610 29.40 2.31 9.46 19.30 9.61 Ref 0 Ref 0 Ref. 17.1 0.0 0 39.06 178.7 0.1659 35.29 2.28 8.93 18.63 13.90 Ref 0 0 Ref 0 Ref. 17.1 0.0 0 39.33 179.4 0.1615 41.18 2.14 8.64 18.45 13.50 Ref 0 Ref 0 Ref. 139 0 0 33.09 166.8 0.1499 52.94 1.88 9.04 17.20 13.50 Ref 0 Ref 0 Ref. 159 0 0 0 133.09 166.8 0.1499 52.94 1.88 9.04 17.20 13.50 Ref 0 Ref 0 Ref. 159 0 0 0 133.11 166.9 0.1499 58.82 1.77 10.88 16.81 13.40 Ref 0 Ref 0 Ref. 167 0 0 0 133.11 166.9 0.1499 58.82 1.77 10.88 16.81 13.40 Ref 0 Ref 0 Ref. 159 0 0 0 0 148.65 203.1 0.1823 76.47 1.41 15.51 15.80 16.43 Ref 0 130 Ref. 130 Ref. 130 Ref 0 130 Ref. 131 Ref. 131 Ref 0 130 Ref 0 130 Ref 0 130 Ref. 131 Ref. 131 Ref. 131 Ref 0 130 Ref 0 130 Ref 0 130 Ref. 131 Ref. 131 Ref. 131 Ref 0 130 Ref 0 130 Ref. 131		55	33.98	168.7		25.53	म् ट	10.71	20.00	10.59		Ref.	•						f. 17		
58 38.33 179.4 0.1655 2.28 8.93 18.68 13.50 Ref 0 Ref 0 Ref. 200 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		75	38.13	178.7	0.1610		2.3	9.48	19.30	9.61	!		1						f. 17		0 18
58 38.33 179.4 0.1615 41.18 2.14 8.84 18.45 13.50 Ref 0 Ref 0 Ref. 155 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	· 2	57	38.06	178.7	0.1609		2.28	8.93	18.68	13.90		Ref.	•				_				
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33.11 166.9 0.1499 58.8e 1.77 10.88 16.81 13.40 Ref 0 Ref 0 Ref. 187 0 54.12 214.3 0.1925 64.71 1.61 12.35 16.45 9.10 Ref Ref. Ref 0 Ref. 154 0 65.15 0.1851 76.47 1.41 15.51 15.80 7.95 Ref 0 180 Ref 0 1 Ref. 193 0 1.55 0.1765 Ref. 36.53 Ref 0 180 Ref 0 1 Ref. 185 0 1.55 0.156 0.1570 15.63 6.63 Ref 0 180 Ref 0 1 Ref. 189 0 1.56.22 175.1 0.1570 94.12 1.14 12.10 15.15 4.31 Ref. 0 0 180 Ref 0 Ref. 166 11		9	33.09	166.8		\$.5°	1.88	₽.6	17,20	13.50									f. 16		
54.12 214.3 0.1925 64.71 1.61 12.35 16.45 9.10 Ref 0 Ref. 164 0 Ref. 163 0 Ref. 163 0 Ref. 163 0 0 Ref. 163 0 Ref. 163 0 0 Ref. 163 0 Ref. 164 0 Ref. 163 0 Ref. 164 0 Ref. 164 0 Ref. 165 0 Ref. 166 Ref. 165 0 Ref. 166 Ref. 166 11 Ref. 166 0 Ref. 166 Ref. 166 0 Ref. 166 Ref. 166 0 Ref. 166		19	33.11	166.9	0.1499	. 28 . 82	1.77	10.88	16.81	13.40		Ref.				1			£. 18		
50.16 206.2 0.1851 70.59 1.52 13.80 16.13 8.65 Ref 180 Ref 0 Ref. 193 0	> A	62	54.12	214.3	0.1925		19.1	ह. उ	16.45	9.10		Ref.		Ref.		1			H		
48.65 203.1 0.1823 76.47 1.41 15.51 15.80 7.95 Ref 0 180 Ref 0 Ref. 185 0 45.65 196.7 0.1765 82.35 1.30 15.00 15.63 6.63 Ref 0 Ref 0 Ref. 189 0 36.22 175.1 0.1570 94.12 1.14 12.10 15.16 4.31 Ref. 0 0 180 Ref 0 Ref. 166 11		63	50.16	206.2	0.1851	70.59	1.52	13.80	16.13	8.65				_		1			£. 15	33	
45.66 196.7 0.1765 82.35 1.30 15.00 15.63 6.63 Ref 0 Ref 0 Ref. 189 0		₫	148.65	203.1	0.1823		1.41		15.80	7.95	Ref.					1			£. 1		
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		99	36.22	175.1	0.1570	,	1.14	. ०१° टा	15.16		Ref.			180	Rof.	1			£. 16		

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TABLE

	Run	£	₽	Мась	Distance of weight		Freq	Frequencies (cps)	in		, .	P. ben.	hase- ling	Phase-angle relationship of bending and torsional stresses (Ref Reference strain-gage trace) (deg)	relat orsion e stra (deg)	tions	hip c tress age t	of ses (race)	_	
		(lb/8q ft)	(fpa)	(fps) number	from root (percent 1)		Natural	Ę,	į		2nd natural mode	ğ		3rd natural mode	urel	apog e		utter	Flutter mode	_
						let	Į.	Ä	Finter	ч	CU	m		2		# E	<u>н</u>	α —	<u>~</u>	#
Model C-1	29	60.42	222.4	222.4 0.2033	0	2.86	17.55	17.55 23.80	15.44	1	Ref.	,	180 Ref.	of		-	- Ref.	162	97	7
Swept, untapered wing; $\Lambda = 60^{\circ}$ Weight moved along leading edge; $\mathbf{e_{W}} = -1$	89	58.60	219.2	219.2 0.2000	90*9	2.86	17.50	2.86 17.50 23.25	15.₩	Ref.	188	0	O Ref.		0	0 180	% Ref.	140	7	0
Reynolds number 😤 8728.3vf	69	51.37	205.2	205.2 0.1870	टा टा	2.86	15.97	2.86 15.97 21.20	14.08	Ref. 180	82	0	O Ref.	<u> </u>	0	0 180	No Ref.	1	8	ន
	70	65.64	201.7	201.7 0.1837	18.18	2.84	12.71	20.35	11.78	Ref.	0	0	O Ref.		0	0 180	% Ref.	8	0	°
	건	48.21	198.7	198.7 0.1810	† ∂*†∂	2.82	2.82 10.31	20.25	8.6	Ref.	-	0	O Ref.	L	0	0 180	So Ref.	38	38	₹
	72	60.24	222.9	0.2030	30.30	47.5		9.20 20.15	8.83	Ref.	죓	0	O Ref.		0	0 180	W Ref.	8	73	88
	73	125.10	324.6	0.2963	36.36	2.63		8.70 20.10	8.33 32.70	Ref.	. 84	0	0	Ref.	0	0 180	So Ref.	Ref. 180	Ref.	i°.
1 = 2.75	7	139.40	344.2	0.3140	टक्-टक्	2.50		8.46 19.80	37.20	Ref.	180	0	O Re	Ref. (0	0 180	o	-	Ref.	<u> </u>
	15	156.00	359.9	0.3330	84.84	2.32		8.80 19.52	04.€4	Ref.	188	0	. 2	Ref. (0	0 180	01		Ref.	°
	92	320.50	540.9	0.4965	45.45	2.16		9.54 19.06	1,8,30	Ref.	180	0	O Re	Ref. (0	0 180	W Ref.	-	196	164
	#	339.40	558.1	558.1 0.5130	60.60	2.01		9.93 18.60	56.00	Ref.	180	0	O Re	Ref. (0	0 18	180 Ref.		190	200
	92	235.50	458.1	458.1 0.4170	66.67	1.85	10.81	18.10	50*25	Ref.	:	0	O Re	Ref. (0	0 18	180 Ref.		0 223	194
Ð	6	129.90	332.8	0.3020	72.72	1.71	11.72	17.90	£0*8T	Ref.	0	0	O Re	Ref. (0	0 18	180 Ref.	. 83	3 318	255
	8	66.95	236.3	0.2140	78.78	1.58	12.38	17.30	9₦*9ፒ	Ref.	0	0	0	Ref.	f		180 Ref.	• 169	64 6	0
	쬢	39.16	179.9	0.1627	48*48	1.48	12.43	96*91 84*21	15.40	Ref.	0	0	O Be	Ref. 180	0		O Ref.	. 180	∄ 0	5
	ଞ	29.86	156.9	156.9 0.1419	90.90	1.35	11.98	00.71 86.11	15.63	Ref.	٥	0	180 Re	Ref. 180	0	Н	O Ref.	191	17	°
	83	56.69	148.2	148.2 0.1340	96.96	1.26	11.30	1.26 11.30 16.96	15.60	Ref.	0	0	-80 -80	180 Ref. 180	0		0 Ref. 155	. 155	33	0
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TABLE

(11) kg t) (fp.) mimber (preparent 1)			. 9	¢	, and a	Distance of welcht		Frequencies (cps)	ncies s)		· · · · · · · · · · · · · · · · · · ·	(Ве	Phase-angle relationship of bending and torsional stresses (Ref. = Reference strain-gage trace) (deg)	Phase-engle relationship of nding and torsional stresses = Reference strain-gage tr (deg)	tle re L tore ance e (de	relati orsiona e straii (deg)	onshi 1 str 1-626	In of reasser	ace)		
94 59.72 224.3 0.2019 0 2.68 17.55 23.80 15.2	Model	<u></u>	(1b/8q ft)	(fps)				latural				atura		-	l nati	Lran	mode		utter	рош	
0 69 60.43 224.4 0.2039 0 2.66 17.55 23.80 15.2							1st			Tutter	<u> </u>	ď	-		- : 	m	_ -	п	2	3	.#
0 69 60.43 224.4 0.2033 6.06 2.90 17.40 24.00 15.40 Ref. 180 7- 0 Ref 0 Ref. 150 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Model C-1	ಪೆ	59.72	224.3	0.2019		2.86	17.55 2		15.2	•							Ref.	150	٥	°
86 63.21 229.6 0.2080 24.24 2.70 12.50 23.30 11.80 Ref 150 Ref 0 Ref. 54 13 87 76.83 256.9 0.2327 30.30 2.74 11.30 22.80 18.70 Ref 150 Ref 0 Ref. 0 20 88 82.87 264.0 0.2330 36.36 2.62 10.70 22.50 18.30 Ref 150 Ref 0 Ref. 0 22 89 75.07 250.9 0.2237 42.42 2.47 10.30 21.50 18.30 Ref 150 Ref 0 Ref. 0 22 90 72.58 246.5 0.2230 48.48 2.00 13.00 19.50 17.10 Ref 150 Ref 0 Ref. 0 13 91 70.53 243.3 0.2139 54.54 2.00 13.00 19.50 17.10 Ref 150 Ref 0 Ref. 0 0 92 74.44 250.0 0.2261 60.60 1.87 15.00 19.10 17.00 Ref 150 Ref 0 Ref. 0 0 93 121.00 321.8 0.2910 66.67 1.70 16.60 18.60 10.20 Ref. 180 0 0 Ref 0 Ref. 20 0 94 113.90 321.8 0.2928 72.72 1.68 17.25 18.70 10.20 Ref. 180 0 0 Ref 0 Ref. 180 0 95 94.17 283.1 0.2555 84.84 1.46 16.50 18.40 Ref. 180 0 0 Ref 0 Ref. 180 0 96 86.02 270.4 0.2438 90.90 1.35 14.80 17.80 7.00 Ref. 180 0 0 Ref 0 Ref. 180 17 17 15 15 15 15 15 15 15 15 15 15 15 15 15	Swept, untapered wing; A = 60°. Weight moved along midchord line; e, = 0°. Desmolds number # 8600.7v.	8	60.43	4°422	0.2033		2.90 1	17.40 2		15.40	Ref.	82	١,	O Re			_ :		160	٥	유
88 82.87 264.0 0.2350 36.36 2.74 11.30 22.80 18.70 Ref 180 Ref 0 Ref. 0 22.		8	63.21	229.6	0.2080		2.78]	12.50 2	3.30	n.80		Ref.		& 8			-		i	13	0
88		87	78.83	256.9	0.2327	L	2.74]	11.30 2	2.80	18.70		Ref.		30 Re			- :			20	33
99 775.07 250.9 0.2270 48.48 2.30 10.90 20.30 17.70 Ref 180 Ref 0 Ref. 0 13.0 13.00 19.50 17.10 Ref 180 Ref 0 Ref. 0 0 0 0 72.50 243.3 0.2159 54.54 2.00 13.00 19.50 17.10 Ref 180 Ref 0 Ref. 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		88	82.87	264.0	0.2390		2.62		2.50	18.30		Ref.		So Re		1	- :		i	Z	댗
91 72.56 246.5 0.2230 48.48 2.30 10.90 20.30 17.70 Ref 180 Ref 0 Ref. 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		&	75.07	250.9	0.2270	ļ	2.47	10.30 2		18.00		Ref.		80 Re						13	92
70.53 243.3 0.2199 54.54 2.00 13.00 19.50 17.10 Ref 180 Ref 0 Ref. 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		8	72.58	246.5	0.2230		2.30	10.90	0.30	17.70		Ref.		80 Re				Ref.		0	82
74.44 250.0 0.2261 60.60 1.87 15.00 19.10 17.00 Ref 180 Ref 0 Ref. 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		. 없	70.53	243.3	0.2199		2.00	13.00	9.50	17.10		Ref.		80 Re						0	89
113.90 321.8 0.2910 66.67 1.70 16.60 18.60 10.20 Ref. 180 0 0 Ref 0 Ref. 20 0 0 0 13.30 17.72 18.70 10.20 Ref. 180 0 0 Ref 0 Ref. 30 0 0 0 13.30 17.70 18.40 Ref. 180 0 0 Ref 0 Ref. 180 17.10 17.10 Ref. 180 17.10 Ref. 180 17.10 17.10 Ref. 180 17.10 Ref. 180 17.10 17.10 Ref. 180 Ref 0 Ref. 180 17.10 Ref. 180 17.10 Ref. 180 17.10 Ref. 180 Ref 0 Ref. 180 17.10		84	14.47	250.0	0.2261		1.87	15.00 1	9.10	17.00		Ref.		80 Re						0	72
94.17 283.1 0.2555 84.84 1.46 16.50 18.40 8.00 Ref. 180 0 0 Ref 0 Ref. 30 0 0 Ref 0 1.35 14.80 17.70 Ref. 180 0 0 Ref 0 1.86f. 17.75 15 15 15 15 15 15 15 15 15 15 15 15 15		8.	121.00	321.8	0.2910		1.70	16.60	18.60			180	0	O RB							180
94.17 283.1 0.2555 84.84 1.46 16.50 18.40 8.00 Ref. 180 0 0 Ref 0 Ref. 180 86.02 270.4 0.2438 90.90 1.35 14.80 17.80 7.00 Ref. 180 0 0 Ref 0 Ref. 175 75 253.1 0.2280 96.96 1.27 13.30 17.70 6.20 Ref 180 Ref 0 Ref. 180		đ	113.90	312.2	0.2823	ļ	1.68	17.25	18.70			180	0	O Re							ᄗ
86.02 270.4 0.2438 90.90 1.35 14.80 17.80 7.00 Ref. 180 0 0 Ref 0 Ref. 175 75.72 253.1 0.2280 96.96 1.27 13.30 17.70 6.20 Ref 180 Ref 0 Ref. 180		82	71.46	283.1	0.2555		1.46	16.50	04.81	8.00		180	0	O Re				Ref.		1	°
75.72 253.1 0.2280 96.96 1.27 13.30 17.70 6.20 Ref 180 Ref 0 Ref. 180		%	86.02	270.4	0.2438		1.35	14.80	17.80	1		180	0						175	1	25
		97	75.72	253.1	0.2280		1.27	13.30	17.70	6.20		Ref.	•	- 80 - 188					180		8

TABLE I.- TEST DATA - Continued

	,	6 -	P +	Mach	Distance of weight		Frequ	Frequencies (cps)			(Re	Fha bendi f. =	ng an Refer	Phase-engle relationship of bending and torsional stresses (Ref. = Reference strain-gage trace) (deg)	laticalistralists	onehi 1 str n-gre	tp of resses	(60)		
МОДӨТ	E	(lb/sq ft)		(fps) number			Matural		: E	Sad 1	2nd natural mode	l mod	— —	3rd natural mode	rel 1	врош	E 1	Flutter mode	pou	
	-					lat	Dag.	Ä	Turrer	1	cv .	m	17	∾	3	≉	н	- cv	m	- 4
Model C-2	98	50.17	207.3	0.1854	0	2,37 1	14.61	g.13	12.80	-	Ref.		O Ref.	-	0	-	Ref.	٥	٥	0
Weight moved along leading edge, $e_{\rm W} = -1$	83	49.22	205.5	0.1835	8.33	2.35	14.40	20.50	22.80		Ref.	,	O Ref.	٥	0	180	Ref.	0	0	0
. Reynolds number = 7932.2v _f	100	42.65	191.0	0.1705	13.88	2.35 1	्रधः य	17.93	11.80	-	Ref.	-	O Ref.		0	82	Ref.	0	0	0
	101	38.75	182.1	0.1625	19.44	2.34	10.68 17.43	17.43	9.80	Ref.	0	0	O Ref.	r. 0	0	180	Ref.	0	ន	8
	198	37.06	178.2	0.1590	25.00	2.30	9.09	17.40	45.8	Ref.	0	-	O Ref.	٥.	0	180	Ref.	342	٥	0
1	103	47.58	202.3	0.1805	30.55	2.27	8.28	17.35	7.61	Ref.	0.	0	O Ref.	0	٥	180	Ref.	23	×	1₹
	형	80.29	264.8	0.2360	36.11	2.15	7.69	17.34	7.30	Ref.	0	0	O Ref.	1	0	188	Ref.	93	92	33
00.5	105	123.90	332.3	0.2960	79.14	2.10	7.42 17.24	17.24	31.35	Ref.	0	0	O Ref.	r.	0	180		Ref.	195	195
	106	148.70	367.7	0.3260	47.22	1.98	7.59 16.92	16.92	35.30	Ref.	0	0	O Ref.	r. 180	0	180	Ref.	323	168	391
	107	193.80	1,24.7	0.3759	52.77	1.85	7.87	16.40	43.20	Ref.	0	0	O Ref.	r. 180	0	180	Ref.	197	्य य	150
	208	265.50	507.0	0.4485	58.33	1.80	8.54	15.96	50.30	Ref.	0	0	O Ref.	. 180	0	180	Ref.	189	197	197
	108	251.80	6.464	0.4349	63.89	19.1	9.23 15.51	15.51	20.20	Ref.	0	0	O Ref.	. 180	0	180	180 Ref.	319	227	198
Ø	ä	131.70	348.8	0.3060	44.69	1.52 10.20 15.07	0.20		16.14	Ref.	0	0	O Ref.	8	0	081	Ref.	T	236 2	214
	E	99.99	243.2	0.2145	75.00	11.11 84.1	1.11	89.41	14.58	Ref.	٥	0	O Ref.	. 180	0	180	180 Ref.	295	320 8	295
	77	36.68	179.6	0.1584	80.56	1.32	נ 36 בנו	14.22	13.33	Ref.	0	0	O Ref.	0	0	0	Ref.	23	0	떑
	113	23.61	143.6	0.1265	11.98	1.25	1.20	14.38	13.44	Ref.	0	0	180 Ref	0	0	0	Ref.	350	23	#
	7	21.24	136.2	0.1200	79.16	1.15	10.53 14.60		13.61	Ref.	0	0	180 Ref.	0	0	0	Ref.	† T	0	340
	115	26.00	150.8	0.1330	97.22	1.06	9.88 14.77		13.40	Ref.	0	0	180 Ref.	٥	0	٥	Ref.	٥	61	337
												1	-]	1	1	İ	1



Concluded
DATA -
H
MALE

(1b) 47 (7b) number Front Front Test 2nd 3rd 2nd		c	þ	4	Distance		Frequ (c	Frequencies (cps)	m		.	Ph bend 3f. =	Ang e Rofe	Phase-angle relationship of bending and torsional stresses (Ref. = Reference strain-gage trace) (deg)	relatores e etre	tions pal s sin-e	unip stress	of Bee trace	<u>~</u> ·		
116 h7.92 205.3 0.1813	Model		(1b/sq ft)	(fps)	number	from root (percent 1)		Nature	4		+	natur	<u>1</u>	-	ard na	ture	l mod		Flutter mode	er i	epc
0 117 50.37 210.2 0.1835 0 2.37 14.61 21.30 14.10 Raf				-			#	P. G.	Ħ	Flutte		2	3	4	н				CI	m	#
0 117 50.37 210.2 0.1856 13.88 2.35 13.59 21.35 12.14 Ref 0 Ref 0 0 118 61.43 233.1 0.2059 30.55 2.22 9.45 20.00 16.65 Ref 0 Ref 0 0 119 63.45 236.9 0.2093 36.11 2.17 9.11 19.72 16.10 Ref 0 Ref 0 0 120 65.31 240.3 0.2123 41.67 2.11 8.88 19.71 16.05 Ref 0 Ref 0 0 122 68.67 235.5 0.2086 52.77 1.87 9.67 17.88 16.54 Ref 0 Ref 0 0 123 66.84 243.2 0.2149 58.33 1.74 10.61 18.16 15.89 Ref 0 Ref 0 0 124 103.70 305.1 0.2659 63.89 1.63 11.85 17.54 12.80 Ref. 0 - 0 Ref 0 125 93.74 289.3 0.2559 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref 0 126 64.49 238.9 0.2119 86.11 1.22 13.46 16.67 7.20 Ref 0 Ref 0 127 69.85 248.9 0.2119 96.11 1.22 13.46 16.67 7.20 Ref 0 Ref 0 128 64.49 238.9 0.2119 97.22 1.05 11.5 16.20 3.48 Ref. 180 0 Ref 0 Ref 0 129 56.57 223.5 0.2074 97.22 1.09 11.15 11.50 0.15 18.16 0 Ref 0 Ref 0 129 56.57 223.5 0.2179 97.22 1.09 11.15 11.50 0.15 18.16 0 Ref	del C-2	779	26.74	205.3	0.1813	0	2.37	14.61	21.30				•	-		:		- 2		27	87
119 63.43 233.1 0.2059 30.75 2.22 9.45 20.00 16.65 Raf 0 Raf 0 0 119 63.45 236.9 0.2093 36.11 2.17 9.11 19.72 16.10 Raf 0 Raf 0 120 65.31 240.3 0.2123 41.67 2.11 8.88 19.71 16.05 Raf 0 Raf 0 122 62.67 239.5 0.2080 52.77 1.87 9.61 17.88 16.54 Raf 0 Raf 0 123 66.84 243.2 0.2149 58.33 1.74 10.61 18.16 15.89 Raf 0 Raf 0 124 103.70 305.1 0.2659 69.44 1.49 13.17 17.20 10.64 Raf. 0 - 0 Raf 0 125 93.74 289.3 0.2159 69.44 1.49 13.17 17.20 10.64 Raf. 0 - 0 Raf 0 126 84.37 274.4 0.2427 75.00 1.41 14.10 16.90 9.90 Raf. 0 - 0 Raf 0 127 69.89 248.9 0.2199 86.11 1.22 13.46 16.67 7.20 Raf 0 Raf 0 128 66.44 238.5 0.2197 97.10 1.26 11.65 11.65 16.21 6.17 Raf 0 Raf 0 129 66.57 223.5 0.2197 97.22 1.09 11.15 10.06 3.48 Raf. 10.0 Raf 0 Raf 0 129 56.57 223.5 0.2197 97.22 1.09 11.15 10.06 3.48 Raf. 10.0 Raf 0 Raf 0 129 56.57 223.5 0.2197 97.22 1.09 11.15 10.09 3.48 Raf. 10.0 Raf 0 Raf	olght moved along midchord line; $\mathbf{e_y} = 0$ ynolds number $\cong 7901.0v_{\mathrm{f}}$	117	50.37	210.2	0.1856		2.35	13.59	21.35			. Ref.							±.	347 2	21 339
120 65.31 240.3 0.2023 36.11 2.17 9.11 19.72 16.10 Ref 0 Ref 0 120 65.31 240.3 0.2123 41.67 2.11 8.88 19.71 16.05 Ref 0 Ref 0 122 62.67 235.5 0.2080 52.77 1.87 9.67 17.88 16.34 Ref 0 Ref 0 123 66.84 243.2 0.2149 58.33 1.74 10.61 18.16 15.89 Ref 0 Ref 0 124 103.70 305.1 0.2699 63.89 1.63 11.85 17.34 12.80 Ref. 0 - 0 Ref 0 125 93.74 289.3 0.2599 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref 0 126 84.37 274.4 0.2427 75.00 1.41 14.10 16.99 9.99 Ref. 0 - 0 Ref 0 127 69.85 248.9 0.2199 86.11 1.22 13.46 16.67 7.20 Ref 0 Ref 0 128 64.49 238.9 0.2110 91.67 1.16 12.66 16.21 6.17 Ref 0 Ref 0 129 56.77 233.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 Ref 0 Ref 0 129 56.77 233.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 Ref 0 Ref 0		87	61.43	233.1	0.2059	30.55	2.22	9.45	20.00												•
120 65.31 240.3 0.2123 41.67 2.11 8.88 19.71 16.05 Ref 0 Ref 0 122 62.67 235.5 0.2080 52.77 1.87 9.67 17.88 16.54 Ref 0 Ref 0 123 66.84 243.2 0.2149 58.33 1.74 10.61 18.16 15.89 Ref 0 Ref 0 124 103.70 305.1 0.2699 63.89 1.63 11.85 17.54 12.80 Ref. 0 - 0 Ref 0 125 93.74 289.3 0.2599 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref 0 126 64.49 238.9 0.2110 91.67 11.81 14.10 16.90 9.90 Ref. 0 0 Ref 0 128 64.49 238.9 0.2110 91.67 1.16 12.66 16.21 6.17 Ref 0 0 Ref 0 129 56.57 223.5 0.2074 97.22 1.09 11.15 10.00 3.48 Ref. 180 0 0 Ref 0 129 56.57 223.5 0.2074 97.22 1.09 11.15 10.00 3.48 Ref. 180 0 0 Ref 0		119	63.45	236.9	0.2093	ж.п	2.17	9.11	19.72				ı								# #
122 62.67 235.5 0.2080 52.77 1.87 9.67 17.88 16.54 Red 0 Red 0 124 103.70 305.1 0.2699 63.89 1.63 11.85 17.54 12.80 Red. 0 - 0 Red 0 125 93.74 269.3 0.2427 75.00 1.41 14.10 16.90 9.90 Red. 0 - 0 Red 0	~	120	65.31	240.3	0.2123	19.14	2.11	8.88	19.Tr							_				1	-
122 62.67 235.5 0.2080 52.77 1.87 9.67 17.88 15.54 Ref 0 Ref 0 123 66.84 243.2 0.2149 58.33 1.74 10.61 18.16 15.89 Ref 0 Ref 0 124 103.70 305.1 0.2699 63.89 1.63 11.85 17.54 12.80 Ref. 0 - 0 Ref 0 125 93.74 289.3 0.2559 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref 0 126 84.37 274.4 0.2427 75.00 1.41 14.10 16.90 9.90 Ref. 0 - 0 Ref 0 127 69.85 248.9 0.2199 86.11 1.22 13.46 16.67 7.20 Ref 0 0 Ref 0 128 64.49 238.9 0.2110 91.67 1.16 12.66 16.21 6.17 Ref. 1 0 0 Ref 0 129 56.57 223.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 0 Ref 0			57.79	226.0	0.1996		1.96	9.6	18.80			Ref.						Re		33	50
66.84 243.2 0.2149 58.33 1.74 10.61 18.16 15.89 Ref 0 Ref 0 103.70 305.1 0.2699 63.89 1.63 11.85 17.54 12.80 Ref. 0 - 0 Ref 0 93.74 289.3 0.2559 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref 0 84.37 274.4 0.2427 75.00 1.41 14.10 16.90 9.90 Ref. 0 - 0 Ref 0 69.85 248.9 0.2199 86.11 1.22 13.46 16.67 7.20 Ref 0 Ref 0 64.49 238.9 0.2110 91.67 1.16 12.66 16.21 6.17 Ref. 1 0 Ref 0 Ref 0 56.57 223.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 Ref 0 Ref 0		227	62.67	235.5	0.2080		1.87	9.67	17.88	ľ		Ref.						Re	£.	0	84 0
103.70 305.1 0.2699 63.89 1.63 11.85 17.54 12.80 Ref. 0 - 0 Ref 0 0 93.74 289.3 0.2559 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref		123	₩.99	243.2	0.2149		1.74	19.01	18.16			Ref								29	£4 0
93.74 289.3 0.2559 69.44 1.49 13.17 17.20 10.64 Ref. 0 - 0 Ref 0 6 Ref 0 R		† 27	103.70	305.1	0.2699		1.63	11.85	17.54				,			-		Re	r.	0	-
84.37 274.4 0.2427 75.00 1.41 14.10 16.90 9.90 Ref. 0 0 Ref. 0 Ref. 0		125	93.74	289.3	0.2559	1	1.49	13.17	17.20				•							12	10
69.85 248.9 0.2199 86.11 1.22 13.46 16.67 7.20 Ref 0 0 Ref 0 0 64.49 238.9 0.2110 91.67 1.16 12.66 16.21 6.17 Ref 0 0 Ref 0 0 56.57 223.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 0 Ref 0		126	84.37	4.47S	0.2427	75.00	1,41	14.10	16.90							-				16 2	St 148
64.49 238.9 0.2110 91.67 1.16 12.66 16.21 6.17 Ref 0 0 Ref 0 56.57 223.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 0 Ref 0		127	69.85	248.9	0.2199	11.98	1.22	13,46	16.67			!	٥							91	•
56.57 223.5 0.1974 97.22 1.09 11.15 16.00 3.48 Ref. 180 0 0 Ref 0		128	64.49	238.9	0.210		1.16	99.21	16.21									_		19 2	25 19
		129	56.57	223.5	4761.0	97.22	1.09	11.15	16.00		T	180		0		-		- BE		:	71 61

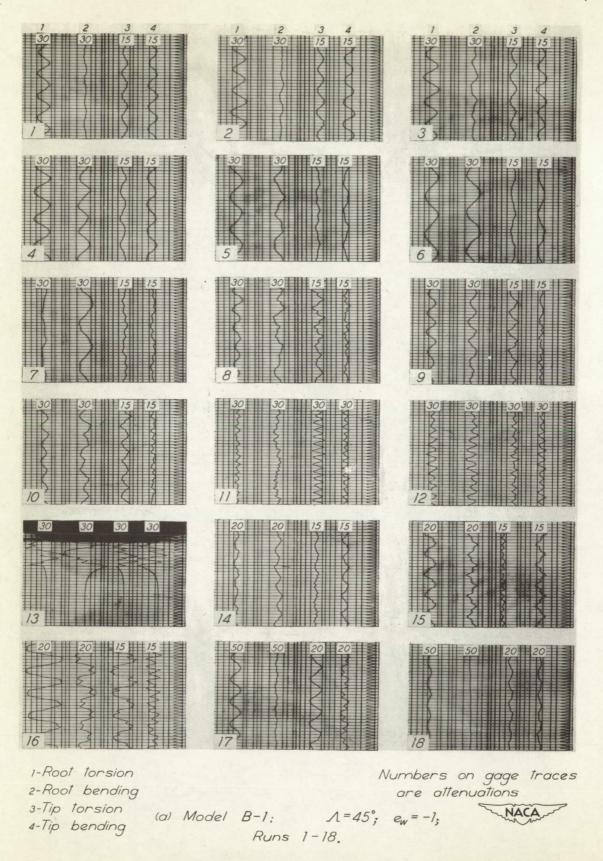
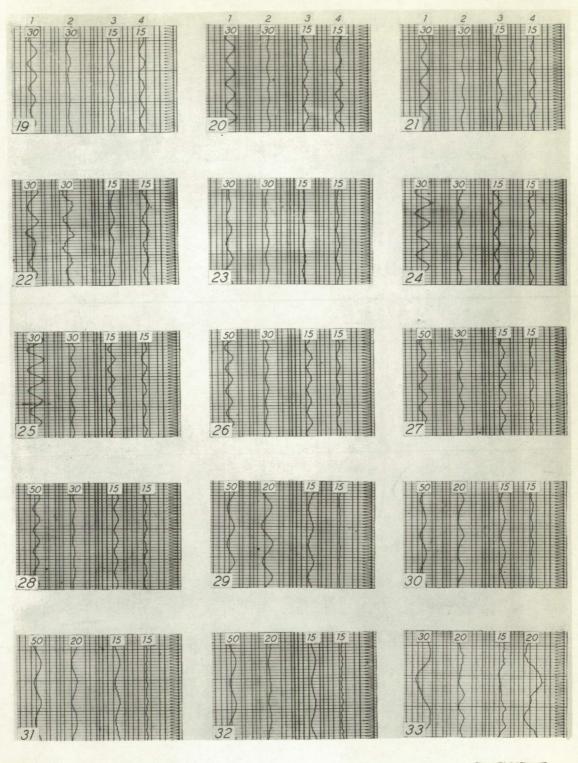


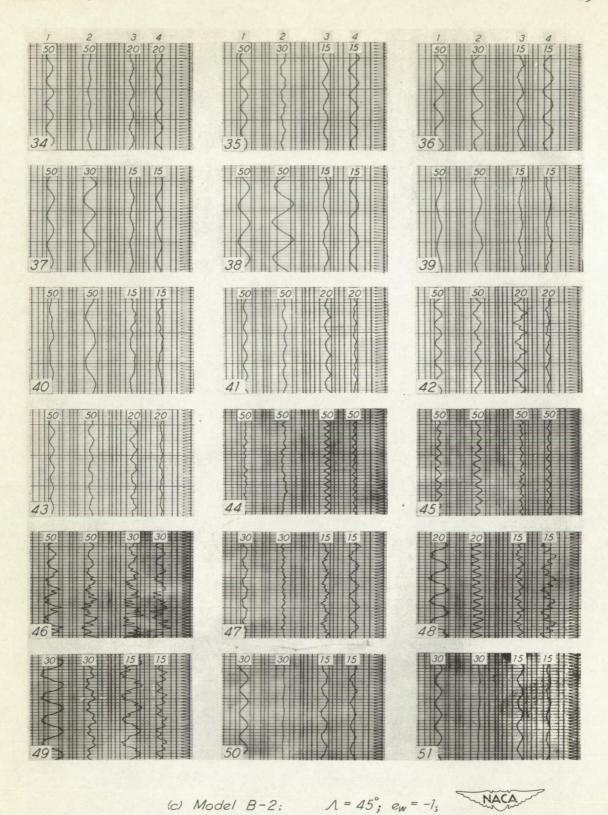
Figure 1.- Oscillograph records taken at flutter.



(b) Model B-1; $\Lambda = 45^{\circ}$; $e_W = 0$; Runs 19-33.

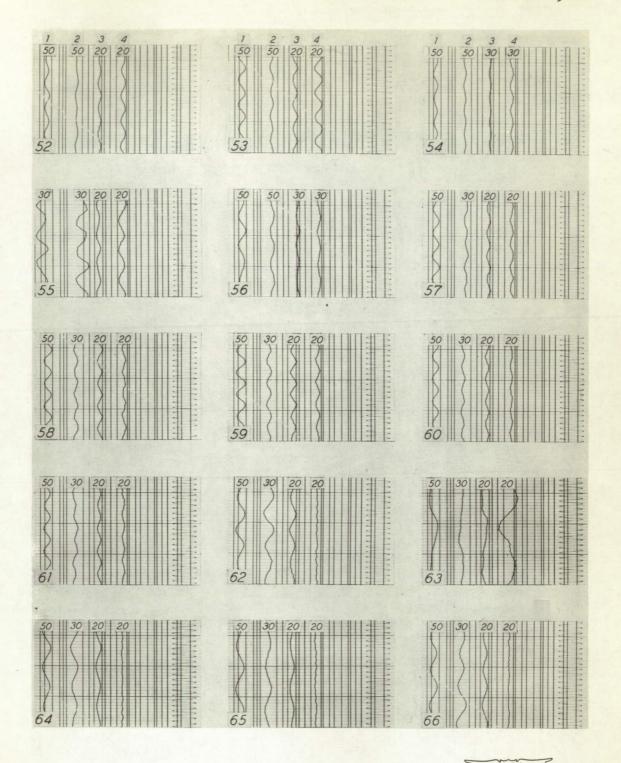
NACA

Figure 1 .- Continued.



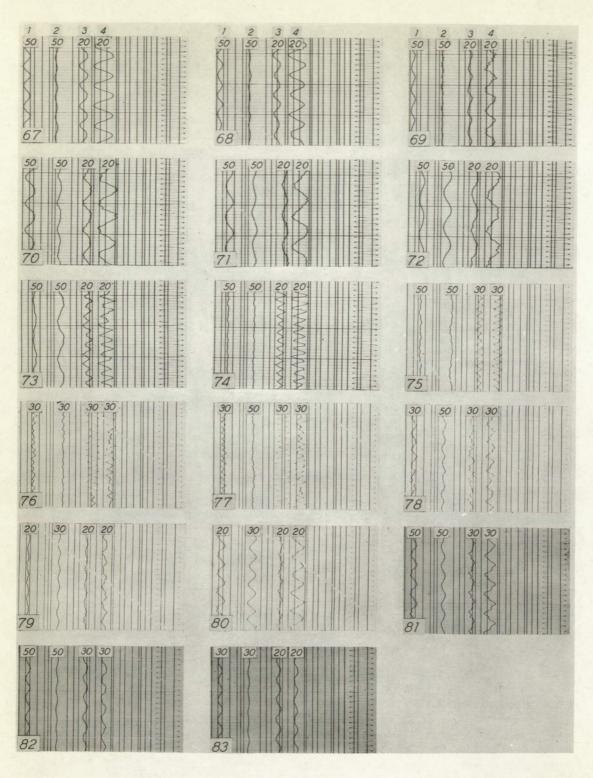
(c) Model B-2: $\Lambda = 45^{\circ}$; $e_W = -1$; Runs 34 - 51.

Figure 1.- Continued.



(d) Model B-2; $\Lambda = 45^{\circ}$; $e_w = 0$; Runs 52-66.

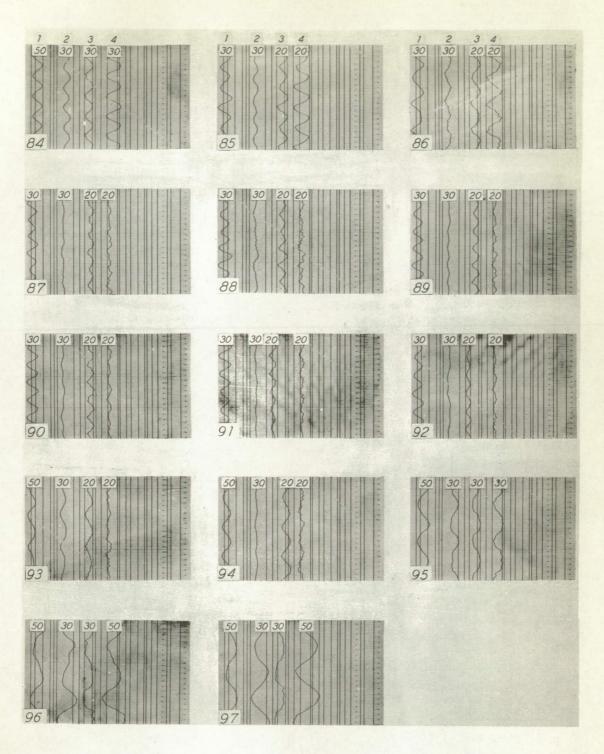
Figure 1.- Continued.



(e) Model C-1; $\Lambda = 60^{\circ}$; $e_w = -1$; Runs 67 - 83.

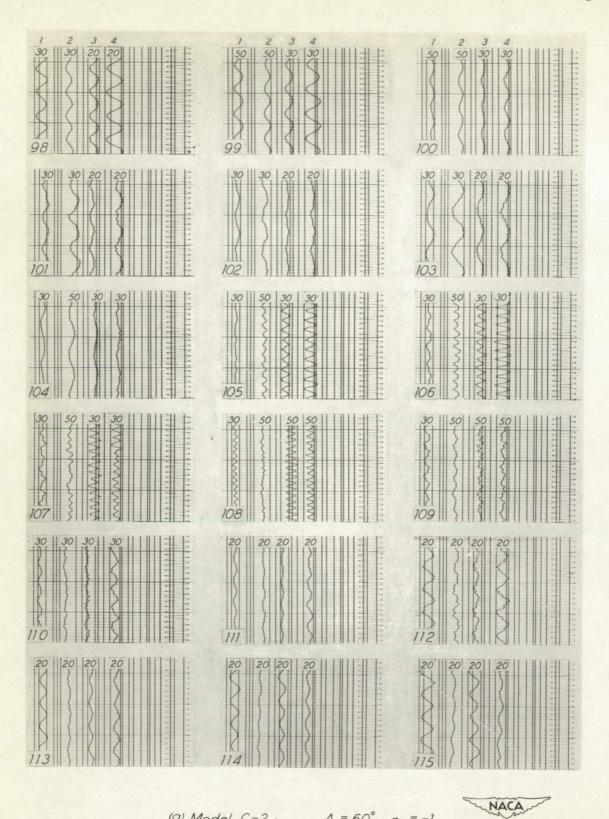
Figure 1.- Continued.

NACA



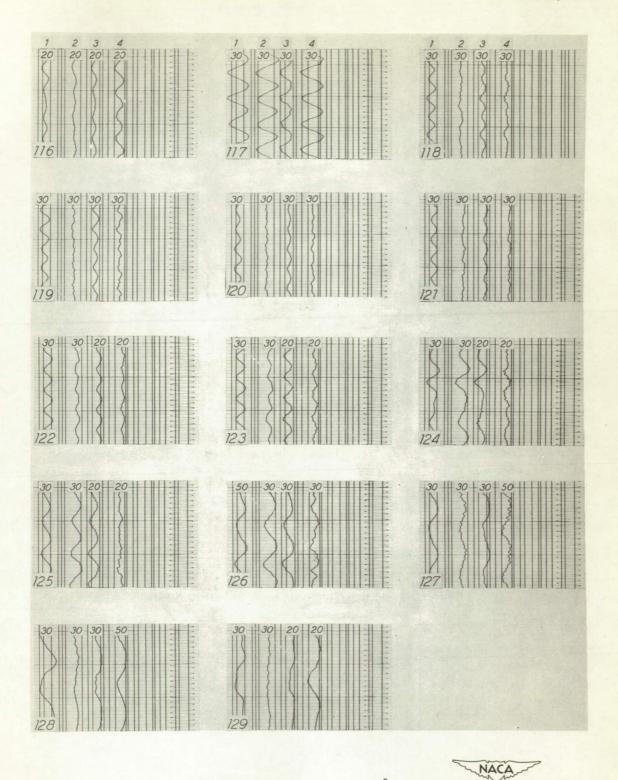
(f) Model C-1; $\Lambda = 60^{\circ}$; $e_{W} = 0$; NACA.

Figure 1.- Continued.



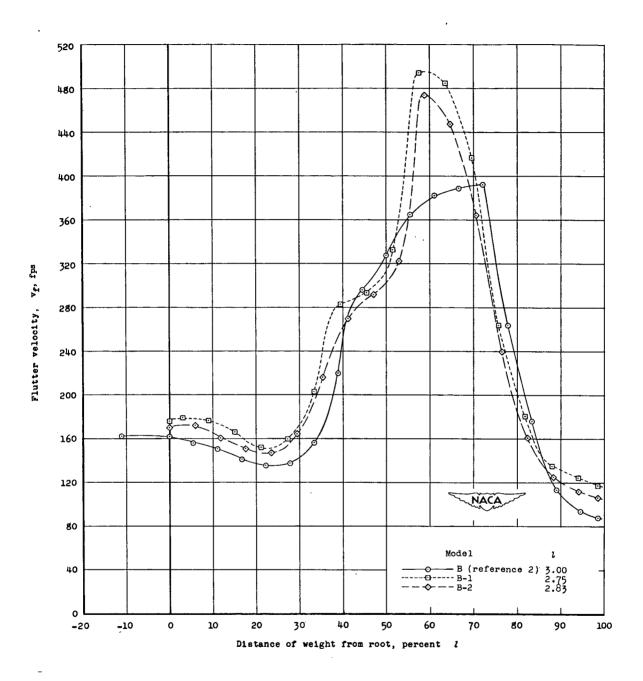
(g) Model C-2; $\Lambda = 60^{\circ}$: $e_{W} = -1$; Runs 98-115.

Figure 1 .- Continued.



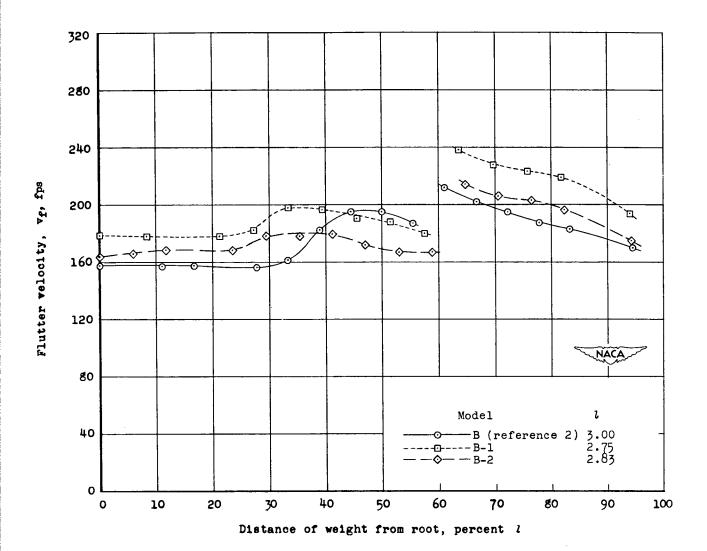
(h) Model C-2; $\Lambda = 60^{\circ}$; $e_W = 0$; Runs 116-129.

Figure 1.- Concluded.



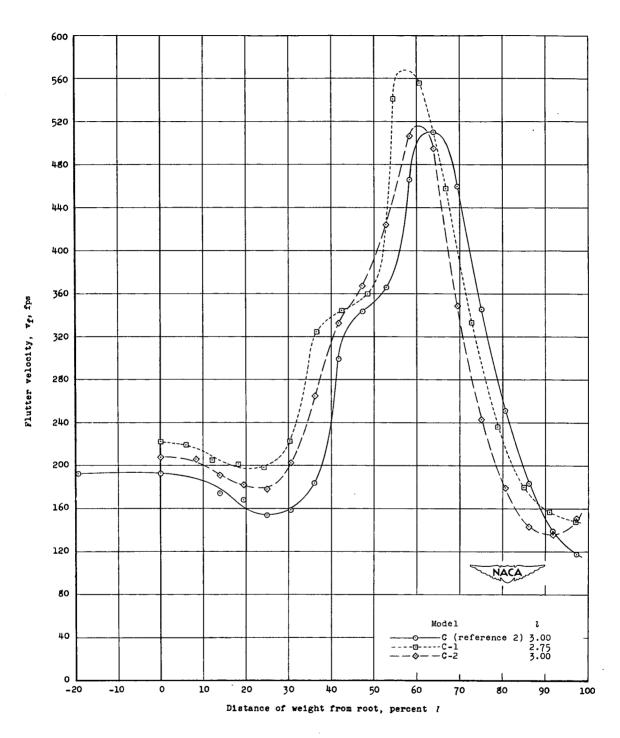
(a)
$$\Lambda = 45^{\circ}$$
, $e_{W} = -1$.

Figure 2.— Variation of the flutter speeds with weight position for each of the models tested.



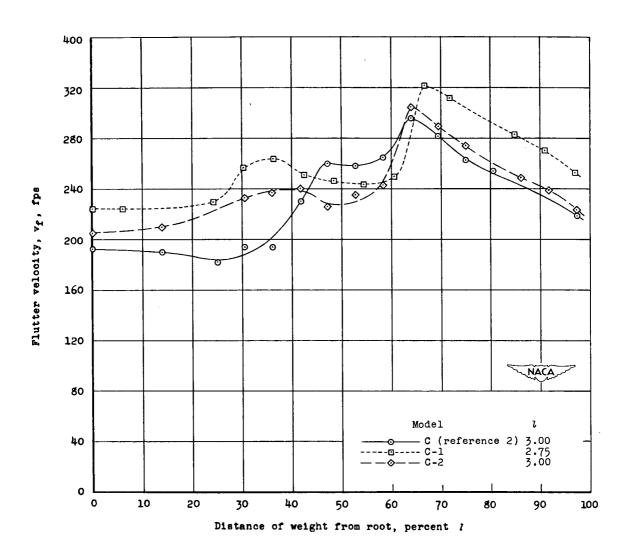
(b)
$$\Lambda = 45^{\circ}$$
, $e_{w} = 0$.

Figure 2.- Continued.



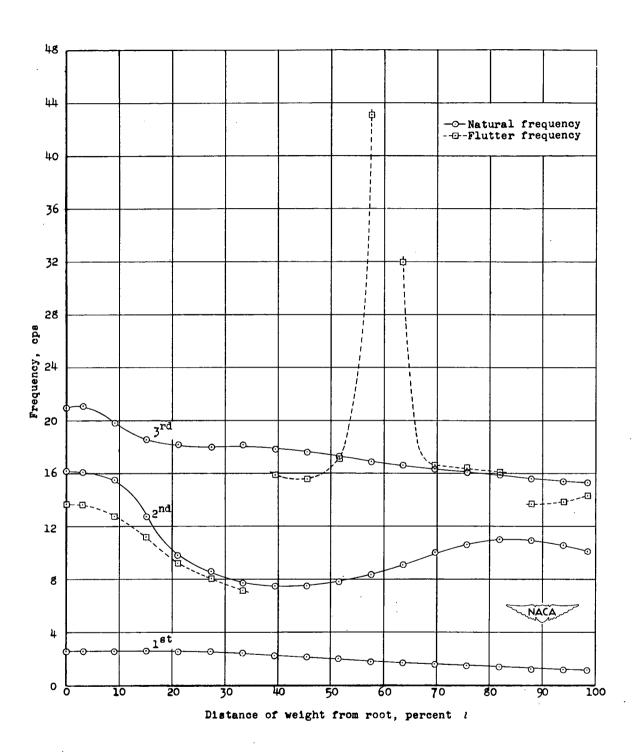
(c)
$$\Lambda = 60^{\circ}$$
, $\Theta_{W} = -1$.

Figure 2.- Continued.



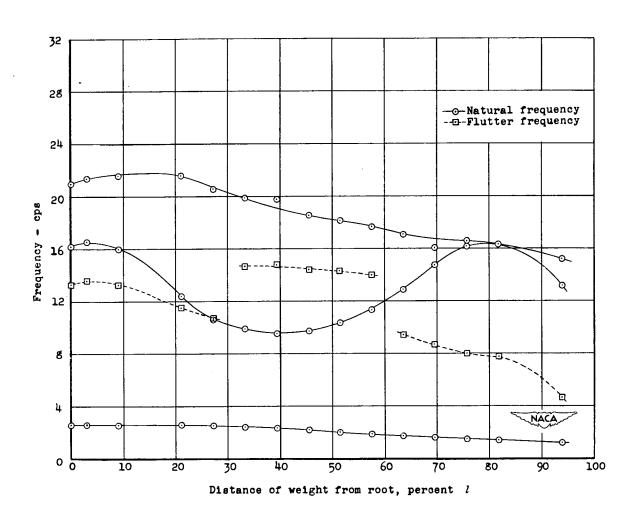
(d)
$$\Lambda = 60^{\circ}$$
, $e_{W} = 0$.

Figure 2.- Concluded.

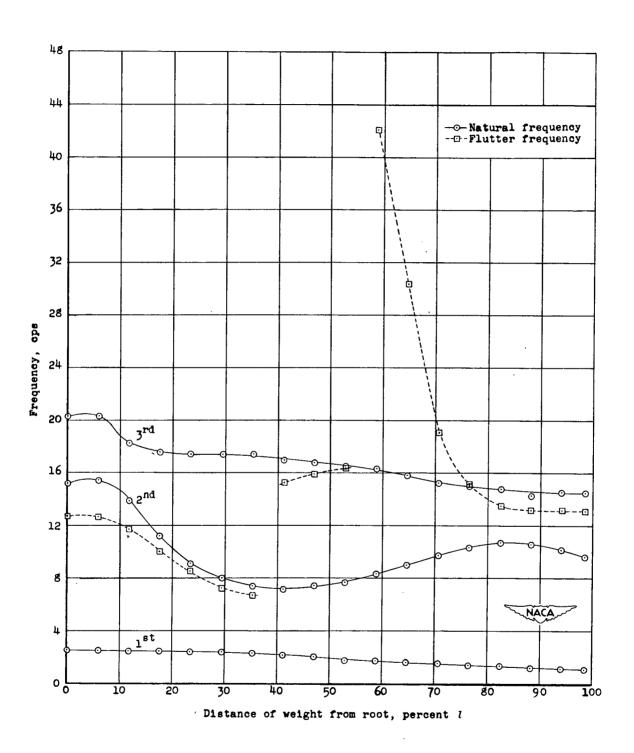


(a) Model B-1, $\Lambda = 45^{\circ}$, $e_{w} = -1$.

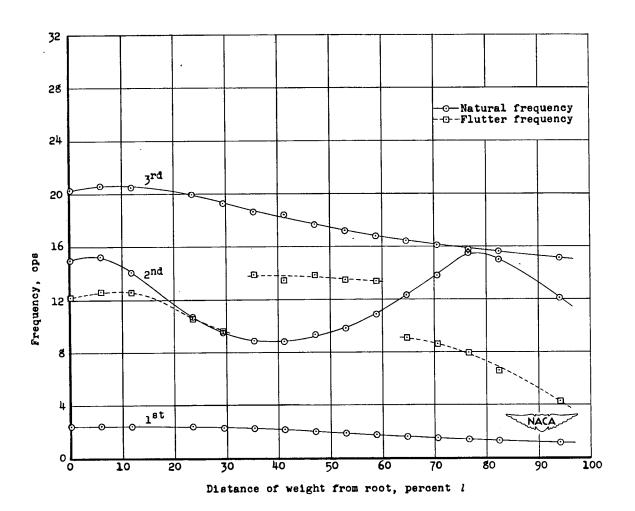
Figure 3.— Variation of the first three natural frequencies and flutter frequency with weight position.



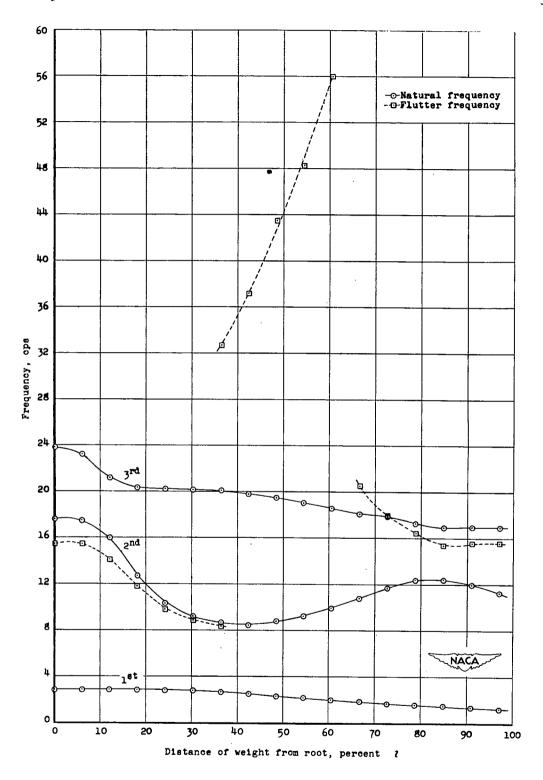
(b) Model B-1, $\Lambda = 45^{\circ}$, $e_{w} = 0$. Figure 3.- Continued.



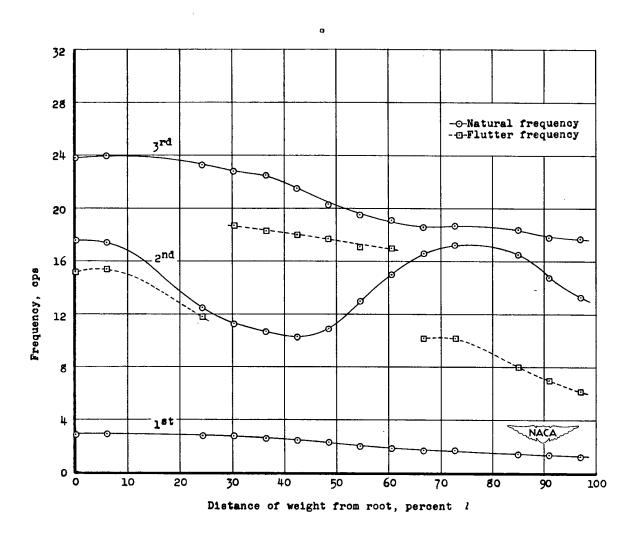
(c) Model B-2, $\Lambda = 45^{\circ}$, $e_{W} = -1$. Figure 3.— Continued.



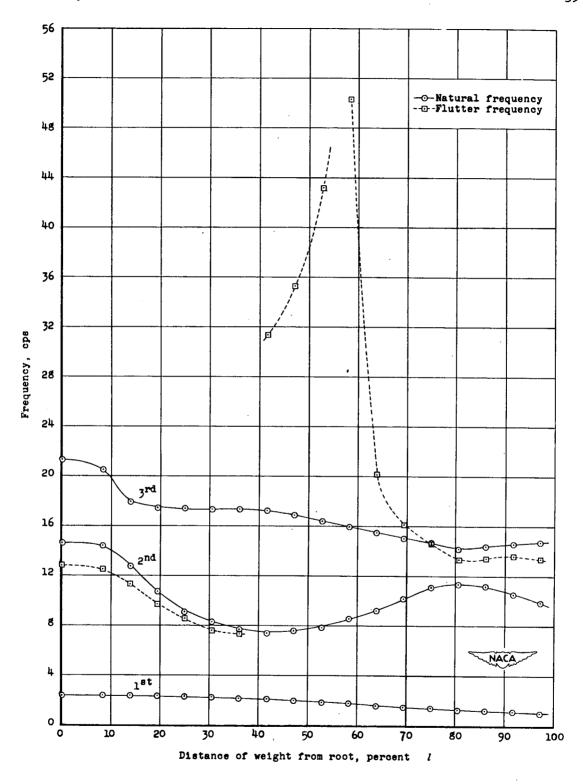
(d) Model B-2, $\Lambda = 45^{\circ}$, $e_{W} = 0$. Figure 3.- Continued.



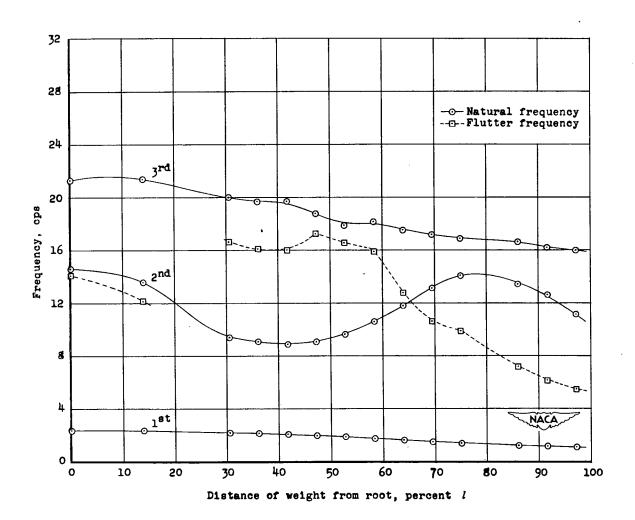
(e) Model C-1, $\Lambda = 60^{\circ}$, $e_{W} = -1$. Figure 3.— Continued.



(f) Model C-1, $\Lambda = 60^{\circ}$, $e_{\mathbf{W}} = 0$. Figure 3.— Continued.



(g) Model C-2, $\Lambda = 60^{\circ}$, $e_{W} = -1$. Figure 3.- Continued.



(h) Model C-2, $\Lambda = 60^{\circ}$, $e_{\mathbf{W}} = 0$. Figure 3.— Concluded.